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THE PROBLEM OF THE HARMLESSNESS OF USING FOOD PRODUCTS STERILIZED BY MEANS OF IONIZING RADIATION

/This is a translation of an article written by G. M. Yegiazarov (Moscow) in Voprosy Pitaniya (Problema of Nutrition), Vol. 19, No. 1, Moscow, 1960, pages 63-66./

In employing radioactive radiations, the required sterilizing effect takes place at very high doses of irradiation, of the $2 \cdot 10^6$ rep order, and even higher. The use of such massive irradiation poses a very important problem, whether under these circumstances an artificial (induced) radioactivity originated in the food products. It is known further that as a result of the action of ionizing radiation there appear undesirable secondary changes in the physico-chemical and organoleptic indices of the sterilized products. This, in turn, poses the question of the possibility of formation of new chemical combinations in the food products possessing toxic properties in various degrees.

All this has been the subject of various experimental investigations and theoretical discussions.

The task of this article consists of summing up certain data on the safety of food products which had been exposed to the action of ionizing radiation.

It has been established (Baldwin, Clark, 1953) that irradiation of yeast with X-rays of an energy order of 100 mev leads to the formation of half-life radioactive isotopes -- basically oxygen, carbon, and nitrogen -- which possess a half-life maximally of 2.1 minutes. A similar phenomenon was observed also by Summer (1952) at a gamma-ray energy above 21 mev. In other experiments (Mayneord, Martin, Layne, 1949) the induced radioactivity was already observed at 17 mev radiation energy. It has been determined (Horsley, Johns, Haslam, 1953) that artificial radioactivity, produced by X-rays of 24 mev energy, constituted approximately 0.6 percent of the obtained dose. Although Baker, Taboada, and Wiant (1954) noted no appearance of radioactivity resulting from a stream of accelerated electrons possessing energy up to 21 mev on grain and flour, Hannan (1954) recommends, for

the sake of safety in cold sterilization, the use of radioactive sources whose radiation energy does not exceed 10 mev. B. Ye. Proctor and S. A. Goldblith (1956) arrived at the same figure by theoretical computation. They established the fact that induced radioactivity can not generally originate in food products upon their irradiation with a stream of fast electrons and gamma-rays of an energy below 8-10 mev. Sher, Halpern, Mann (1951) and many other authors (McElhinney, Hanson, Becker, Duffield, Diven (1949; Baldwin, Koch, 1945) worked on ascertaining the energy-threshold which determines the appearance of artificial radioactivity in the most important elements encountered in food products. Some of these data are cited in the table below.

The Energy Threshold and the Half-Life of Certain Elements Encountered in Food Products

Element	Energy threshold (in mev)	Half-life period of the isotope
C^{12}	18.7	21 minutes
O^{16}	16.3	2.1 "
N^{14}	10.65	10 "
P^{31}	12.35	25 "
K^{39}	13.2	7.5 seconds
S^{32}	14.8	3.2 "
Ca^{40}	15.9	1 "
Mg^{24}	16.2	11.6 "
Cu^{63}	10.9	10 minutes
J^{127}	9.3	13 days
Br^{81}	10.7	6.4 minutes
Si^{28}	16.8	5 seconds
H^{2}	2.2	very short

However, as noted by R. S. Hannan (1957), this radioactivity was not measured directly in the products. In fact, repeated checking of the food products subjected to irradiation up to 10 mev invariably brought negative results concerning induced radioactivity. At this irradiation energy, the residual radioactivity was not elicited even at a dose which exceeded the sterilization dose approximately three fold, i. e., at $6 \cdot 10^6$ rep.

In addition to determining the induced radioactivity

in the food products themselves, Meinke (1954) carried out tests on the irradiation of various food products with gamma-rays from a powerful cobalt source. In this instance, too, he did not succeed in detecting artificial radioactivity even with the use of the most sensitive dosimetric apparatus.

R. S. Hannan (1957) thinks that, though the use of electromagnetic radiation of an energy up to 10 and even 15 mev does not present any difficulty at present, when fast electrons of high radiation energy are used for sterilization undesirable phenomena of radioactivity may appear. Therefore, additional experiments are needed in this field.

There are a number of publications in which the authors demonstrated the harmlessness of irradiated products. Thus, for example, Brownell (1952, 1953, 1954), Luckey, Wagner, Reyniers, Foster (1955), while conducting experiments at Michigan University, obtained satisfactory results in feeding irradiated products, including milk, to three generations of mice. Bubl and Butts (1956) fed four generations of rats for two years with meat-product derivatives irradiated with a dose of $3 \cdot 10^6$ rep; no phenomena of intoxication were detected in the experimental animals. Beta-rays, according to reports by Poling, Warner, Humburg, etc. (1955), do not cause formation of toxic substances in beef which would affect the number born or the weight of rats (the experiments were carried out on three generations of animals, a total of 2685 individuals, and the irradiation dose was two million rep). According to the data of G. I. Bondarev (1958), rats which had been fed for four months on beef, codfish filet, and green peas irradiated with gamma-rays (dose -- 1.5 million rep), did not differ from the control animals in their survival capacity, weight dynamics, or general condition, nor in the morphology of the peripheral blood.

L. A. Okuneva (1958) observed no deviation in the growth, development, conduct, blood morphology, and enzymic activity of the blood in rats which had been fed for a period of 10 and 12 to 14 months potatoes irradiated with radioactive cobalt (dose consisted of 10,000 and 50,000r); neither did the author detect any difference in the number of progeny or in their development. Analogous data were obtained also in experiments on dogs which had been fed irradiated potatoes for eight months.

Satisfactory results were reported by Wasserman, Trum (1955), Kuprianoff (1956), Teply, Kline (1956) and other authors who had experimented on mice, rats, dogs, chicks, and monkeys (A. N. Liberman, 1957; Da Costa, Levenson, 1953; Urbain, 1953).

Ryer (1956) reports on the results of observations

conducted in the United States on volunteers. Rations consisting of 35 to 100 percent of irradiated products did not cause any toxic effect on the human organism. Nappan, Colby (1957) and other authors also report satisfactory results in a number of similar observations.

However, in some cases, entirely different results were obtained. Thus, in experiments in 1927 (Narat), a growth retardation was observed in mice which had been fed irradiated food. Kraybill (1955,1956) also demonstrated that feeding irradiated food to rats caused in these animals a depression of their sexual functions and a higher mortality in young individuals. Becker, Kung, Barr, Pearson, King (1956) noted diminished fertility in rats which had been fed butter irradiated with gamma-rays (dose -- $1.68 \cdot 10^6$r). The tests were conducted on three generations of animals. The observed fact was explained by the authors as vitamin E insufficiency, this vitamin being easily destroyed by high energy radiation. A number of other authors arrived at a similar conclusion. To verify this statement, Kraybill, Read, Friedemann (1956) kept rats on irradiated vegetable and animal food to which the necessary amount of vitamins was added. Though the capacity for proliferation was reestablished in this case, it was lower in the experimental group than in the control.

B. N. Tarusov (1957) and K. I. Zhuralev (1957) noted that as a result of the radiolysis of fats, compounds possessing toxic properties may accumulate. N. I. Matusov (1956) called attention to the possibility of formation of toxic substances harmful to health.

As the result of this, many authors in the USSR as well as abroad (M. N. Meisel, N. D. Chernayev, 1956; A. M. Kuzin, M. N. Meisel, 1956; I. Shur, 1956; T. Bardyshev, V. Mints, 1957; Proctor, 1954; Proctor, Goldblith, 1951; Schweigert, 1954; Lehman, Long, 1954; Friedemann, 1956; Hannan, 1957; Hannan, Coleby, 1957) think that much remains to be clarified in the problem of the safe use of irradiated food products, and that it is essential to carry out additional investigations on a large scale. With this in view, the Food and Drug Administration in the United States suggested certain biological experiments with products irradiated with doses ten times larger than the ones needed for obtaining the necessary sterilized effect. However, this suggestion is objected to by B. Ye. Proctor and S. S. Goldblith (1956). In their opinion an acceptance of this method may lead to erroneous conclusions, since the possibility is not excluded of the destruction of toxic elements (if such will be formed at all) with a higher irradiation dose. Thus, an erroneous conclusion may be made concerning the

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harmlessness of smaller doses of ionizing radiation.

Other authors (Lehman, Long, 1954) stress the fact that, besides all other considerations, the question of the cancerogenicity of the irradiated products has not been completely clarified as yet.

In summarizing the above data, we must note that there is no uniform opinion as yet on the safety of irradiated food products. A considerably larger amount of experimental work will have to be carried out before a final opinion can be formed.

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